J Polym Environ (2007) 15:301–305
DOI 10.1007/s10924-007-0074-3

SHORT COMMUNICATION

Marine Debris & Plastics: Environmental Concerns, Sources, Impacts and Solutions

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Published online: 28 November 2007

Abstract Marine debris (marine litter) is one of the most pervasive and *solvable* pollution problems plaguing the world's oceans and waterways. Nets, food wrappers, cigarette filters, bottles, resin pellets, and other debris items can have serious impacts on wildlife, habitat, and human safety. Successful management of the problem requires a comprehensive understanding of both marine debris and human behavior. Knowledge is key for consumers to make appropriate choices when it comes to using and disposing of waste items. Education and outreach programs, strong laws and policies, and governmental and private enforcement are the building blocks for a successful marine pollution prevention initiative. The plastic industry also has a role to play in educating its employees and customers, and searching for technological mitigation strategies.

Keywords Marine debris · Marine litter · Environmental impact · Plastic debris

Defining Marine Debris

Marine debris (marine litter) is any manufactured or processed solid waste material (typically inert) that enters the ocean environment from any source [1]. Debris, and particularly debris composed of plastic, is one of the world's most pervasive pollution problems affecting our oceans and inland waterways.

Ocean dumping has been practiced for centuries, during which time the nature of marine debris has changed dramatically. Decades ago, much of our waste was made of organic, degradable materials. Now, synthetic elements, like plastics, are an abundant material in solid waste. Plastic beverage bottles, packing straps, tarps, and synthetic fishing line are durable, slow to degrade and buoyant, becoming debris with staying power. Because of high buoyancy, plastic items have been found to travel in currents for thousands of miles, endangering marine ecosystems and wildlife along the way.

Plastic debris found in the ocean includes food wrappers, cigarette filters and cigar tips, fishing line, rope and gear, baby diapers and nappies, six-pack rings, beverage bottles, disposable syringes, as well as pre-production resin pellets. All these debris items share a common origin. At a critical decision point, someone, somewhere, mishandled it—either thoughtlessly or deliberately.

While technological advances in plastic materials and the subsequent use of plastics have played a key role in improved packaging, computers, medical equipment, transportation and other aspects of modern life, we must recognize the environmental problems associated with improper waste management, and then identify steps to prevent and eliminate this source of marine pollution.

Sources of Marine Debris

A review of the available data on debris found worldwide indicates that the dominant types and sources of debris come from what we consume (including food wrappers, beverage containers, cigarettes and related smoking

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materials), what we use in transporting ourselves by sea, and what we harvest from the sea (fishing gear). The United Nations Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) determined that land-based sources account for up to 80% of the world's marine pollution [2]. Data from other sources supports this finding. Litter and debris on our streets enters streams and rivers through stormdrains and sewers, is carried from seaside parking lots, and is left on beaches by beach visitors. Boats and ships on the ocean are other sources of debris, as are offshore drilling rigs and platforms, and fishing piers. Trash and litter can travel long distances before being deposited on our shorelines or settling on the bottom of the ocean, bay, or riverbed, making it hard to determine where the debris originated.

Marine debris researchers traditionally classify debris sources into two categories: *land-* or *ocean/waterway-based*, depending on where the debris enters the water. Ocean current patterns, climate, tides, and proximity to urban centers, industrial and recreational areas, shipping lanes, and commercial fishing grounds influence the type and amount of debris that is found on the open ocean or collected along beaches and waterways or under water.

Land-Based Debris Sources

Land-based debris starts on streets, parks, parking lots, and other surfaces. The debris then is washed, blown or discharged into nearby waterways by rain, snowmelt, and wind. Sources include inappropriate or illegal dumping of domestic and industrial garbage; public littering; poorly covered dumpsters and dump trucks; manufacturing sites, processors, and transporters; sewage treatment and combined sewer overflows; beachgoers; fishermen; shore-based solid waste disposal and processing facilities. Both legal and illegal waste handling practices contribute to marine debris. These include the inadvertent release of debris from landfills and garbage from water transports. Littering packaging from convenience items, food wrappings, beverage containers, and a host of other materials creates the foundation for the marine debris problem.

Ocean/Waterway-Based Debris Sources

Marine debris is also generated by people's actions and activities at sea. Ocean and waterway-based debris can come from commercial fishing vessels; merchant, military, and research vessels; recreational boats and cruise ships; and offshore petroleum platforms and associated supply vessels. Some debris enters the water from accidental loss or system failure, while other debris comes from poor waste management practices, and illegal disposal. Commercial and recreational fishermen create marine debris when they discard ship-generated trash overboard or fail to retrieve nets, ropes, trawl floats and other fishing related gear.

Impacts of Marine Debris

Marine debris is a global issue, affecting all the major bodies of water on the planet—above and below the water's surface. This debris can negatively impact humans, wildlife, habitats, and the economic health of coastal communities.

Human Health and Safety

Visitors to a beach can be harmed from broken glass, medical waste, fishing line, and discarded syringes; swimmers, divers and snorkelers can become entangled in submerged or floating debris. Medical and personal hygiene debris (including condoms and tampon applicators) that enters waterways through direct sewage outflows or inadequate sewage treatment systems also presents serious water quality concerns that affect human health and safety. The presence of these items indicates that bacterial contamination, including *E. coli*, other harmful bacteria, and viruses, may be found in these waters. Consumption or contact with water polluted with these contaminants and pathogens can result in infectious hepatitis, diarrhea, bacillary dysentery, skin rashes, and even typhoid and cholera.

Aesthetic and Economic Impacts

Debris makes shorelines unattractive and potentially hazardous, and forces communities and governments to spend funds for beach maintenance. Many coastal communities rely on the income generated by seaside businesses, so the indirect costs of a littered beach can be great. Marine debris discourages people from fishing, boating, swimming, and visiting coastal areas.

Wildlife Entanglement and Ingestion

Entanglement in nets, fishing line, ropes and other debris poses a huge threat to wildlife, especially those that live near or on the water. A seabird, sea turtle, dolphin or other marine animal that becomes ensnared faces the risks of being strangled or even drowned because of their entanglement. Debris can hamper an animal's mobility, prevent it from

eating, inflict cuts and wounds, or cause suffocation or drowning. Monofilament line, fishing nets and ropes, ribbons on balloons, six-pack rings, and packing strapping bands are some of the more harmful culprits related to entanglements. According to the U.S. Marine Mammal Commission, 136 marine species have been reported in entanglement incidents, including six species of sea turtles, 51 species of seabirds, and 32 species of marine mammals [3].

Ingestion of debris by animals is another serious problem. Plastic pellets can look like fish eggs, and plastic shopping bags can look like a jellyfish to a hungry sea turtle. Many animals confuse debris for food and cannot regurgitate an item once it has been swallowed; it often becomes lodged in their throats and digestive tracts. Debris that will not pass out of the stomach gives a false sense of cessation, causing some animals to stop eating and slowly starve to death. The U.S. Marine Mammal Commission reports that ingestion incidents have been documented in six of seven species of sea turtles, 111 out of the world's 312 species of seabirds, and 26 species of marine mammals [3].

Derelict fishing gear has been found to be lethal to ocean life for years after fishermen no longer use it. In a process called *ghost fishing*, an abandoned fishing net will continue to catch and kill ocean life [4]. There is increasing recognition of the worldwide ghost fishing problem and the impact it is having on the viability of already stressed fisheries [5].

Habitat Destruction & Alien Species Introduction

Debris can physically damage shoreline, living coral reef, and other important habitats. Ropes, nets and tarps are moved by currents and tides, and can abrade, scour, break, smother, and destroy fragile aquatic habitats. Ensnared debris may also smother sea grass or corals, and can cause increased siltation and turbidity, blocking essential sunlight. Another concern is that drifting debris can host entire communities of encrusting and attached organisms and transport them great distances to areas where they can harm or compete with native species as invasives.

Vessel Damage

Nets, ropes and other derelict fishing gear can cause serious damage to vessels by entangling propellers and rudders. Plastic bags are a common cause of clogged and blocked water intakes, resulting in burned-out water pumps in recreational boats. Such incidents cause costly repairs, loss of time, and danger to boaters and crews. The true scope and frequency of damaging encounters between debris and vessels is difficult to calculate, as most incidents go unreported.

Less Understood Impacts

While research has been done on the harm marine debris can cause to humans, wildlife, habitat and vessels, there are many environmental impacts that are less well understood. These include:

- Source and fate of microscopic fragments/plastic fibers.
- Accumulation and dispersion of toxic substances found in or on plastic.
- Disturbance from mechanical beach cleaning has been shown to interfere with sea turtle nesting. What other impacts does beach cleaning have?
- Impact of marine debris on the species at the base of the food chain.
- Bio-transfer of pollutants.

Related Issues

Scientific literature on the management and conservation of living marine resources show that marine debris is right up there along with other concerns about over fishing, by-catch, pollution, and other human activities. Solving the marine debris problem is an important tool as we strive for sustainable fisheries and the conservation of sensitive aquatic habitats.

Prevention, Reduction and Control of Marine Debris

Like other environmental problems, marine debris can be prevented and controlled through an effective collaboration of education, legislation, and innovation.

Educating the Public and Industry

Everyone needs to take responsibility for their actions and keep their trash out of the marine environment—from school children, to people who eat fast food; recreational boaters and commercial fishermen; beach visitors and marina operators; waste management workers, and workers in all industries that transport or manufacture resin pellets. Every piece of debris and litter found in our waterways at one point involved a person who made an improper decision. In a way, it can be said that every piece of debris has human fingerprints on it. Knowledge is key for consumers

to make appropriate choices when it comes to using and disposing of waste items.

There are many marine debris and litter-prevention activities and lesson plans available by various government agencies and school systems. In many cases, the manufacturers of plastic items have participated and supported their creation and dissemination. For example, the company that manufactures six-pack rings, ITW Hi-Cone, created an educational video, lesson plan, and a recycling program for schools. In addition, they modified the resin to increase photo-degradability.

Educational materials have also been produced for various audiences by Ocean Conservancy, U.S. National Oceanic and Atmospheric Administration, U.S. Environmental Protection Agency, the U.S. Coast Guard, United Nations Environmental Programme and many other government agencies and nonprofit organizations.

A critical part of successful education includes a complete understanding of the problem. In the 1980s, Ocean Conservancy began its work on marine debris resulting in the development a public education and monitoring program targeting marine debris.

Gathering Data—International Coastal Cleanup and National Marine Debris Monitoring Program

Ocean Conservancy and its international and domestic partners have grown the International Coastal Cleanup (ICC) into a global annual volunteer effort devoted to the marine environment. The ICC engages schools, marinas, civic organizations, government agencies, and businesses as volunteers to conduct local cleanup events. One of the ICC's primary goals is to trace pollution to its source and work to prevent it from occurring. Volunteers record debris information on standardized data cards that identify the types, sources, and activities that produce the debris found along the world's beaches and waterways. Information on the data card is grouped by the behavior associated with the debris, including recreational, beach-going activities, smoking-related activities, ocean and waterway activities, activities associated with legal or illegal dumping, or activities resulting from improper disposal or handling of medical or personal hygiene materials. The result is a unique global database of debris information. Data from the Cleanup provides the framework for government action to limit marine debris and to educate the public about litter and pollution prevention. Information on the ICC, including data and contacts for local cleanup activities, are posted at www.oceanconservancy.org/ICC.

Through a multi-year cooperative agreement with the U.S. Environmental Protection Agency, Ocean Conservancy developed and field-tested a scientific marine debris-monitoring program designed to assess the effectiveness of current U.S. marine debris legislation (MPPRCA & MARPOL Annex V). The National Marine Debris Monitoring Program (NMDMP) assesses several aspects of debris, including accumulation rates, types and amounts of debris found at specific geographic locations, oceanographic and meteorological conditions, and proximity to land-based or ocean-based sources. The final NMDMP report is posted for public access through Ocean Conservancy's website at www.oceanconservancy.org/nmdmp.

Engage Relevant Stakeholders

Stakeholders, including local citizens; governments, agencies and authorities (national, regional, and local); organizations (nonprofit, consumer, civic, international/national, religious, and nongovernmental); institutions (research, medical, and education); businesses (convenience stores, hotels, restaurants, outdoor recreation, manufacturers, and vendors); and industries (fisheries, tourism, waste management, and dive) must be involved in the effort to effectively reduce and control marine debris and its environmental impacts.

Business/Industry Involvement

Much of the debris found worldwide is attributable to what we consume: food, beverages, tobacco products and other consumer goods. Other large categories of marine debris come from transportation, fishing, and manufacturing. The industries affiliated with these products and services must commit to taking on a responsible role in debris management and abatement. Only with their involvement and support can we create effective solutions to the debris problem [6].

The plastic industry has taken steps to understand the true nature of durable and degradable plastic materials and their behaviors in the environment. For more than 20 years, the plastics industry has joined forces with Ocean Conservancy regarding the presence of plastic materials and their impacts on the marine environment. The result was the formation of a triple alliance between industry, the conservation community, and government agencies with the mission of educating industry employees and consumers about the problems of marine debris. A national ad campaign was developed to help build awareness of boating and fishing groups about the impacts of fishing gear and packaging materials that are allowed to enter the marine environment.

The Dow Chemical Company provides an example of a company actively supporting the efforts to decrease marine debris. Dow has sponsored the International Coastal Cleanup for the past 20 years, has aided efforts in the

Northwestern Hawaiian Islands for Monument designation, and has worked with Ocean Futures and Jean-Michel Cousteau on an education campaign on marine debris. Other companies, like ITW Hi-Cone and Philip Morris USA have directly approached their customers with litter-prevention messages. Philip Morris has mailed pocket ashtrays to their customers as part of a campaign to decrease the number one type of litter—cigarette filters.

The Society of the Plastics Industry in partnership with the American Plastics Council (now the American Chemistry Council) developed "Operation Clean Sweep," a program to train employees to prevent resin pellets spills, and raise awareness for industry-based responsibility for the raw plastics materials that are being introduced into the environment. Pellets, the raw material for most plastic items, can be accidentally introduced into the environment by pellet manufacturers, by those who transport pellets, and by the end user. Most litter prevention programs target the consumer—but this program is focused on employees of the companies that manufacture products from plastics. Zero pellet loss is key to the industry's ability to conserve resources, promote plant safety, and ultimately protect the environment.

Implement Legislation and Enforce Regulations

Several laws and international agreements regulate litter and debris on both land and sea. The current laws relevant to the marine debris issue include the *1972 London Dumping Convention (LCD)* and the *International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)*, which provides a comprehensive approach to dealing with ocean dumping by creating international guidelines to prevent ship pollution. MARPOL prohibits the disposal of plastic materials at sea and regulates the disposal of other garbage at sea. MARPOL also requires ports and terminals to provide garbage reception facilities for boats and ships.

There are also regional agreements to govern marine debris, including the 1987 Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region—known as the Cartagena Convention. This legally binding environmental treaty for governing marine debris in the Wider Caribbean requires countries to adopt measures to prevent, reduce, and control pollution from ships, dumping, seabed activities, land-based activities, and airborne pollution.

Many states and national governments also have anti-litter laws, bans on the mass-releases of balloons, and regulations to prevent accidental discharge of waste from dump trucks and dumpsters.

Unfortunately, laws do not guarantee compliance. In addition to enforcement and penalties, a sense of environmental stewardship among ocean users is essential for laws to be effective. While there are laws regulating the dumping of trash at sea and on shore, the global nature of debris, its inability to be confined within territorial boundaries, and the complexity of identifying debris sources have made effective laws difficult to draft and even harder to enforce.

Innovation

In addition to education and legislation, some solutions to the plastic marine debris problem will come from innovative technologies that will increase biodegradability and photodegradability of plastics. But it must be said that such technical mitigation strategies will not eliminate the need for education and behavioral changes. There are alternatives to some of the materials and products we are currently using that may be less harmful to the environment, but would require modified waste management strategies.

Conclusion

Despite research on the causes of marine debris, and efforts to educate people about the need for prevention, we continue find litter and debris entering the ocean. All stakeholders must be dedicated to the creation of strategies and opportunities that encourage people to reduce marine debris. We must continue with current efforts by governments and the private sector to increase awareness, establish debris abatement programs, and change behaviors. Controlling and reducing debris in the marine environment is a significant—but achievable—challenge. If we are to conserve our ocean resources responsibly and successfully, it is a challenge that we must all face together.

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